instrument ought to increase, provided it was subjected to the same intensity of radiation while immersed in liquid air or liquid hydrogen.

The experiments, in any case, seem to show that the radiometer may be used as an efficient instrument of research for the detection of small gas pressures and the study of radio-active products. For quantitative measurements the torsion balance or bifilar suspension must be employed. It would be interesting to repeat light repulsion experiments in the highest attainable charcoal vacuum. Later on I hope to extend the investigation.

Some Notes on Carbon at High Temperatures and Pressures.

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Following the subject of my paper of 1888 to this Society, which will be referred to in a subsequent communication, attempts have recently been made to melt carbon by electrical resistance heating under pressure, and the following is a short summary of the results of about 100 experiments.

The procedure has been on two lines. In the first, carbon is treated in bulk in a thick tube of 8 inches internal diameter of gun steel closed below by a massive pole of steel insulated from but gas tight with the mould and above by a closely fitting steel ram packed by copper rings imbedded in grooves in the ram or by leather and steel cups according to whether solids, liquids or gases are to be contained. The bore of the mould is generally lined with asbestos and after being charged the whole is placed under a 2000-ton press, the head and baseplate being insulated and connected to the terminals of a 300-kilowatt storage battery with coupling arrangements for 4, 8, 16 or 48 volts.

It was hoped that the greater thermal and electrical conductivity of steel as compared with carbon or graphite at moderate temperatures would with the help of water jackets keep the outer layers comparatively cool and that the increased conductivity of the central portions consequent on their higher temperature and conversion to graphite would so centralise the current on the core lying between the poles as to melt it.

Further concentration of current was obtained in the initial stages of heating by packing the central portion with carbon rods on end or by a compressed graphite core, and filling in around with coarsely broken arc-light carbon, or with wood charcoal (which is a bad conductor until highly heated).

With pressures of about 30 tons per square inch, and currents commencing

at 6000 ampères, increasing up to 50,000 ampères, with about 2 volts between the terminals of the mould, the carbon rods were partially converted to graphite and firmly welded together; in the case of the graphite core the flakes were much increased in size.

The heating was in all cases limited by the melting of the steel poles and resulted in short circuits in the mould from the permeation of the asbestos by the molten iron. Neither the internal water-jacketing of the poles nor the substitution of copper poles for steel have remedied this trouble.

It appears that the thermal conductivity of the carbon or graphite at or near the temperature of vaporisation is very greatly in excess of that anticipated, or that the rapid transfer of heat is caused by carbon vapour, which appears to have a great power of penetration through carbon at high temperatures. The melting of the poles and the destruction caused by short circuits which reached 80,000 ampères in the mould were not only costly to remedy, but caused contamination of the carbon from the metal of the poles and the insulating material.

In several experiments a nucleus of very soft graphite about $2\frac{1}{2}$ inches in diameter was found in the centre. And in several experiments small masses of iron, highly charged with graphite, were found in varying positions among the carbon or graphite.

This method, however, would probably be more successful if carried out on a much larger scale, as for a given central temperature the transfer of heat to the poles and mould would be less, and water-jackets would then prove more effective. It is, however, difficult to construct water-jackets to withstand more than 30 tons per square inch, and unless made of hard steel they crush in. The maximum power of the press is 2500 tons, and with the apparatus at hand if the size of the mould was much increased the pressure in the mould would have to be decreased.

Another plan was then adopted of interposing an insulating barrier of some refractory material with a hole in it between the poles, the charge in the first instance being graphite. It was hoped that by means of electrical currents of higher potential and large volume the energy would be so concentrated on the small volume in the neck as to melt it before it had time to form carbides with the material of the barrier.

This was to some extent achieved in that the graphite in the centre was converted to a softer and more flaky nature.

In one of these experiments the barrier was formed out of a block of fused magnesium oxide, specific gravity 3·65, and the pressure in the mould, which was 4 inches in internal diameter, was in this case raised to 100 tons per square inch. The strongest steel poles were required for this pressure

also the mould of gun steel became permanently strained and required reboring after each experiment.

A current at about 12 volts at the terminals in the mould, developing about 100 kilowatts, was turned on for seven seconds.

The initial diameter of the hole in the barrier was $\frac{5}{8}$ inch and the thickness about $\frac{3}{4}$ inch.* This barrier was converted to magnesium carbide of a green colour to a radial depth of about $\frac{3}{8}$ inch. Thus this magnesium oxide when heated under pressure with graphite readily forms a carbide. The graphite in the centre was altered to large and very soft flakes. Neither the graphite nor the magnesium carbide contained any hard crystalline carbon.

Similar experiments were tried with carbon rods surrounded by silica, and as a guide to the temperature reached, current was turned on of just sufficient voltage to convert the rod to graphite; the mould was then set up afresh and double the voltage applied, when the rod was vaporised and disseminated throughout the molten silica, principally in the form of graphite of very small grain, very little silicon and still less silicide of carbon being formed.

Another series of experiments have been made to investigate the behaviour of vaporised carbon under fluid or gaseous pressures of about 30 tons per square inch. The general arrangement of the mould consisted of a central carbon rod with a lining of marble; in some cases the space between the rod and marble was packed with coarsely powdered charcoal.

Several compounds of carbon were treated, perhaps the most interesting being carbon dioxide. The liquid was run into the mould and a pressure of 30 tons per square inch applied. It was found that its volume diminished to about 80 per cent., due to its compressibility. Current was then passed through the rod, and the liquid must then have existed as gaseous carbon monoxide in the hotter zones.

When cooled, the liquid and gas were allowed to escape; a sample of this gas on analysis was found to contain 95 per cent. of carbon monoxide and 3 per cent. carbon dioxide, the residue consisting apparently of nitrogen.

As the pressure of 30 tons was maintained throughout the experiment, it would seem that the compressibility of carbon monoxide diminishes rapidly at such high pressures, but this experiment will be repeated and will form the subject of a subsequent paper on the compressibility of liquids and gases. Part of the central carbon was converted to graphite, and in one place there was found a nest of woolly deposited carbon, showing that under a pressure of 30 tons per square inch carbon vaporised in carbon monoxide is deposited in the form of amorphous carbon.

* The heat units delivered on to the neck being about four times that required to raise the graphite column through 5000° C., taking the specific heat at 0·5.

Conclusions.

From these experiments several hundred samples have been carefully analysed. In none of the experiments designed to melt or vaporise carbon under pressure has the residue contained more than a suspicion of black or transparent diamond.

In no experiment we have made has there been any sign of the carbon becoming a non-conductor, and the impression derived is undoubtedly that soft crystals of graphite are the resulting stable form of carbon after heating to very high temperatures.

At very high temperatures and pressures graphite has a great tendency to permeate or diffuse into its cooler surroundings. It should, however, be noted that in all the experiments so far made it has been found impossible to exclude from the graphite other substances in the liquid or gaseous state.

Though in many of the foregoing experiments the molten steel of the poles became highly charged with graphite, further experiments have been made to ascertain the influence of pressure upon iron highly charged with carbon. Cores formed of iron rods, iron tubes filled with carbon or with various proportions of iron filings and lamp black, surrounded with various substances such as charcoal, magnesia, olivine, etc., were melted or vaporised and disseminated throughout the charge.

Thus iron highly charged with carbon under a pressure of 30 to 50 tons was cooled at various rates according to its proximity to the sides of the mould, the analysis showing in most cases no residue at all, but occasionally a suspicion of very minute diamond. As a further experiment, a small carbon crucible containing iron highly charged with carbon from the electric furnace was quickly transferred to a steel die and subjected, while still far above the melting point, to a pressure of 75 tons per square inch.

The analysis showed scarcely any crystalline residue and probably less than if the crucible had been cooled in water at atmospheric pressure, and as it would seem that 75 tons or even 30 tons per square inch must be a greater pressure than can be produced in the interior of a spheroidal mass of cast iron when suddenly cooled, the inference from these experiments seems to be that mechanical pressure is not the cause of the production of diamond in rapidly cooled iron.

We hope to be able to communicate further experiments on this subject during the course of next session.

I would wish to add that most of the analyses have been made by Mr. J. Trevor Cart.